1. IT'S THE WATER!

A working knowledge of water quality is indispensable to the practicing agriculturist-fieldman. Water quality influences initial crop selection and then crop management throughout the life of the crop. In diagnosing field problems, water quality is one of the first things that should be evaluated. The professional agriculturist should be able to quickly scan a water analysis report and pick out pertinent information.

A major obstacle to quick interpretation of water analysis results is that data can be reported in one of several different units. The fieldman must be able to easily convert from one unit to another for interpretation. All that is required is the memorizing (or keeping in a handy place) a few basic rules and conversion factors as outlined in the following.

Reading Data

Water analysis data are reported in one of three units: ppm, mg/l or meq/l (parts per million, milligrams per liter or milliequivalents per liter), ppm and mg/l are identical terms for interpretive purposes. To change from ppm to meq/l (or vice versa), the equivalent weight of the chemical constituent in question must be known, then:

$$\text{equivalent weight} \times \text{meq/l} = \text{ppm (or mg/l)}$$

$$\text{OR}$$

$$\text{ppm (or mg/l)} / \text{equivalent weight} = \text{meq/l}$$

EQUIVALENT WEIGHTS

Cations (+ charged)		Anions (-charged)	
Ca (calcium)	20.0	Cl (chloride)	35.5
Mg (magnesium)	12.2	NO_3(nitrate)	62
Na (sodium)	23.0	SO_4 (sulfate)	48
Ca + Mg	19.2	CO_3 (carbonate)	30
(assume 90% is Ca)		HCO_3(bicarbonate)	61

Examples:

    1. How many ppm is 3.3 meq/l Ca?

    3.3 X 20.0 = 66.0 ppm

    2. How many meq/l is 50 ppm Na?

    50/23 = 2.17 meq/l

In addition, nitrate can be reported either as nitrate (NO_3) or nitrate-nitrogen (NO_3-N), and sulfate can be reported as SO_4 or SO_4-S. To convert nitrate to nitrate-N, divide by

4.4 (50 ppm NO_3 = 11.4 ppm NO_3-N). To convert sulfate to sulfate-sulfur, divide by 3.0 (48 ppm SO_4 = 16 ppm SO_4-S).

Another handy fact in water analysis interpretation is that an acre foot of water weighs 2,716,435 lbs. (or 2.7 million lbs.). Thus water with a nitrate-nitrogen content of 10 ppm (10 lbs. per million lbs.> contains 27 lbs. of N per acre foot. With a normal crop usage of 3 to 4 acre feet of water per season, such a water supplies a considerable portion of a crop's fertilizer needs.

Electrical Conductivity (EC)

EC or Electrical Conductivity is usually reported in millimhos per centimeter (mmhos/cm) and measures the total salt content of water. Multiplying EC by 640 gives a good approximation of the total ppm salt or total dissolved solids (TDS). Multiplying EC by 10 gives a good approximation of the total cation or anión concentration in meq/l.

The symbol "K" is sometimes used in place of EC and EC is sometimes written as EC X 10^{-3} which is the same as mmhos/cm. EC X 10^{-6} is micromhos/cm and can be converted to mmhos by multiplying by 1000. EC X 10^{-5} can be converted to mmhos by multiplying by 100.

Water Classification by Toxic Constituents

The agricultural suitability of water is determined by the concentration of three constituents: sodium, chloride and boron.

A tentative classification is given below:

Table 1. **Classification of Water by Toxic Constituents***

Concentration of constituents

Classification	meq/ l Na	meq/l Cl	ppm B
Excellent	less than 4	less than 3.5	less than 0.3
Good to very good	4 - 6	3.5 - 4.5	0.3 - 0.5
Fair to good	6 - 7	4.5 – 5.5	0.5 – 1.0
Poor to fair	7 - 9	5.5 – 7.5	1.0 – 2.0
Very poor to possibly injurious	9 – 12	7.5 - 10.0	2.0 – 3.0
Very poor and usually injurious	12 - 16	10 - 14	3.0 – 4.0
Injurious to unsuitable if used over a prolonged period of time	over 16	over 14	over 4.0

*the salt and boron tolerance of many crops is given in USDA Handbook 60

The above classification does not consider total salt content, however in virtually all agricultural situations, if a water is excessive in total salt it will be excessive in sodium and/or chloride. (A low total salt content should be taken into consideration because permeability problems can occur with low salt water. Permeability problems are probable when EC is below 0.2 mmhos/cm and possible when EC is between 0.2 and 0.5. Amendment application will offset permeability problems caused by low salt water).

Many researchers refrain from classifying waters because both water management and environmental conditions influence water suitability. The four main conditions under which a very poor quality water could be satisfactorily used are:

1. very low evapotranspiration (cool, overcast climate)

2. drip irrigation

3. a well drained soil kept continually well supplied with water

4. cultivation of only very tolerant crops

The ameliorating effect of environmental conditions on water quality was brought home to me on a visit to a broccoli field in Baja California. Prior to the visit I had seen the water data which showed both sodium and chloride in the 10 to 12 meq/l range. I was confident of seeing considerable leaf burning and plant stunting and was quite surprised when I saw an excellent field of broccoli about to be harvested. The climate was cool (next to the ocean with many foggy days), the soil well drained and kept well supplied with water (furrow irrigation) proving that the effective classification of a water can be changed by both climate and management.

Other Toxic Constituents

Fieldmen in the southwestern U.S. should be aware that some wells contain toxic concentrations of lithium. Also, sewage waters in some areas contain toxic amounts of fluoride, cadmium and other heavy metals.

The classification in Table 1 does not consider a fourth constituent bicarbonate, (some waters also contain carbonate, which is similar to bicarbonate in it's adverse effects; any reference herein to bicarbonate is meant as carbonate + bicarbonate). It is known that bicarbonate in water has direct adverse effects on some plant species (see following chapter). As more research on bicarbonate is published and as more bicarbonate sensitive plants become known, bicarbonate concentration will become an important criterion for determining water suitability for certain crops. Fortunately, the amount of bicarbonate in water can be reduced to safe levels by the addition of acid. Although waters are not currently classified by bicarbonate content as they are by sodium, chloride and boron content, bicarbonate concentration is considered in the calculation of a fourth classification criterion discussed below.

Water Classification A Fourth Criterion

The 3 toxic constituents (sodium, chloride and boron) upon which water classification is based are essentially unchangeable i.e., there is no practical way of reducing high levels of these constituents to safe levels; (under greenhouse culture, water with an excess of sodium, chloride or boron can be run through exchange resins or reverse osmosis systems but this is not yet practical for large scale agriculture). A fourth criterion estimates the sodium hazard of waters and considers the ratio of calcium + magnesium (Ca + Mg) to sodium (Na) and carbonate + bicarbonate (CO_3 + HCO_3).

A low amount of Ca + Mg in relation to Na and CO_3 + HCO_3 can cause soil sealing and consequent poor water infiltration due to a buildup of sodium in the soil. Calcium and magnesium reduce sodium buildup hazard by displacing sodium in the soil. CÜ3+HC03 increase sodium buildup hazard by precipitating calcium and magnesium as carbonates

which have an extremely low solubility.

Four different methods of assessing the potential hazard of soil sodium buildup (or soil permeability problems) are in general use. These 4 methods are discussed below **(note:** in all calculations given below, all concentrations of chemical constituents are given in meq/l):

Sodium Adsorbtion Ratio (SAR)

$$SAR = \frac{Na}{\sqrt{Ca + Mg/2}}$$

SAR was one of the first methods of assessing the potential hazard from sodium buildup but has given way to other methods that consider the $CO_3 + HCO_3$ content. In general, waters with SAR values above 6.0 were considered to represent a sodium hazard, although at a given SAR, low salinity waters were considered much less of a sodium hazard than high salinity waters.

2. Residual Sodium Carbonate (Res. Na_2CO_3 or RSC)

$$RSC = (CO_3 + HCO_3) - (Ca + Mg)$$

Positive values indicate a sodium buildup hazard. Multiplying RSC by 234 gives a gypsum requirement in Ibs. of 100% gypsum/acre ft. of water. (234 is the factor used to convert a calcium deficit or excess from meq/l to Ibs. of gypsum per acre foot of water; if metric units are desired, the factor is 86 and the units are kg of gypsum per 1000 m^3).

RSC was introduced by USDA worker Frank Eaton in 1950 in a paper that has been correctly termed a classic by his peers. Since that time, RSC has become a popular method of assessing sodium hazard and is still used today. Although RSC does not take into account the sodium content of water, it is a simple and usually accurate method of determining potential permeability problems from sodium.

3 Eaton's Gypsum Requirement

Not satisfied with RSC, Eaton introduced the following method of determining the calcium deficit (or gypsum requirement) of water in 1966 (Ibs 100% gypsum/ac. ft.):

$$Gyp. \ Req. = 234 \ (a + b + c), \ where$$

$$a = 0.43 \ Na - (Ca + Mg)$$
$$b = 0.7 \ (CO_3 + HCO_3)$$
$$c = 0.3$$

Positive values indicate a potential sodium buildup hazard. Negative values indicate that the water can deposit gypsum.

Eaton's Gypsum Requirement was the first method of assessing sodium hazard that considered all 3 of the influencing factors: Na, Ca+Mg and $CO_3 + HCO_3$ Although not widely used, Eaton's Gyp. Req. is relatively easy to calculate and has proven reliable.

4 Adjusted Sodium Adsorption Ratio (adj. SAR)

Introduced in 1972, adj. SAR uses pH_c values to modify the SAR to account for the effects of $CO_3 + HCO_3$ (see following page for determination of pH_c):

$$\text{adj. SAR} = \text{SAR}\,(9.4 - pH_c)$$

Soil permeability problems from sodium buildup are likely with adj. SAR values over 6.0. Adj. SAR is being incorporated in many new water quality guidelines and will probably be widely used in the future.

CALCULATING pH_c -

pH_c values are used mainly to calculate adj. SAR values and consider the concentration of Na, Ca+Mg and $CO_3 + HCO_3$. pH_c values will also tell whether a given water will dissolve lime or deposit lime as it passes through the soil.

a, b and c Values for pHc Formula

meq/l	- a -	meq/l	- b -	meq/l	- c -
Ca + Mg + Na	pK'2 - pK'c	Ca + Mg	p(Ca + Mg)	$CO_3 + HCO_3$	$p(CO_3 + HCO_3)$
.5	2.11	.05	4.60	.05	4.30
.7	2.12	.10	4.30	.05	4.30
.9	2.13	.15	4.12	.15	3.82
1.2	2.14	.20	4.00	.20	3.70
1.6	2.15	.25	3.90	.25	3.60
1.9	2.16	.32	3.80	.31	3.51
2.4	2.17	.39	3.70	.40	3.40
2.8	2.18	.50	3.60	.50	3.30
3.3	2.19	.63	3.50	.63	3.20
3.9	2.20	.79	3.40	.79	3.10
4.5	2.21	1.0	3.30	.99	3.00
5.1	2.22	1.25	3.20	1.25	2.90
5.8	2.23	1.58	3.10	1.57	2.80
6.6	2.24	1.98	3.00	1.98	2.70
7.4	2.25	2.49	2.90	2.49	2.60
8.3	2.26	3.14	2.80	3.13	2.50
9.2	2.27	3.90	2.70	4.0	2.40
11	2.28	4.97	2.60	5.0	2.30
13	2.30	6.30	2.50	6.3	2.20
14	2.32	7.90	2.40	7.9	2.10
18	2.34	10.00	2.30	9.9	2.00
22	2.36	12.50	2.20	12.5	1.90
25	2.38	15.80	2.10	15.7	1.80
29	2.40	19.80	2.00	19.8	1.70

$$pH_c = a + b + c, \text{ where}$$

$a = pK'_2 - pK'_c$: (calculated from Ca, Mg, Na)
$b = p(Ca + Mg)$
$c = p(CO_3 + HCO_3)$

pH_c values above 8.4 indicate a tendency to dissolve lime from soil through which the water moves; values below 8.4 indicate a tendency to precipitate lime from waters applied.

pH$_c$ values are helpful in assessing potential clogging problems from calcium carbonate precipitation on drip irrigation systems and in predicting scaling problems (from lime deposition) on pump bowls. An older method of assessing lime deposition, the Langlier index, is easier to calculate and is still used by some labs.

Evaluating the 4 Sodium Permeability Evaluations

Although **SAR** does not consider CO_3 + HCO_3, it can be useful in cases where other methods give excessive weight to CO_3 + HCO_3 (see following section).

adj. SAR will probably become the accepted standard by which to assess potential sodium permeability problems. It has the disadvantage of not being easily calculated (I have seen several calculation errors by labs, so it pays to verify a lab's calculation) and not being easy to explain to a grower.

Residual sodium carbonate is easily calculated, but because it does not consider sodium content, there will be a few cases where other methods are superior.

I have made extensive use of **Eaton's Gyp. Req.** and have found it to be a useful and reliable tool. It also gives a good handle on the amount of gypsum deposited by a water useful when making gypsum recommendations.

A comparison of the 4 methods is shown in the following.

Water Examples

Analysis of 8 waters is given in Table 2 along with observed permeability problems, if any, associated with each.

Table 2. Water Analysis Data for Eight Different Waters***

No.	Description	Permeability Problems?	Year Sampled	pH	EC mmhos/cm	$Ca+Mg$	Na	CO_3+HCO_3	Cl	SO_4	pH_c	SAR	adj. SAR	Resid. Na_2CO_3	Eaton's Gyp. Req.**
						meq/l							Permeability Evaluation		
CALIFORNIA WELLS															
1.	A	Yes	1971	7.8	0.38	1.00	2.46	0.69	1.5	1.2	8.7	3.5	2.6	0	+197
2.	B	Yes	1975	9.3	0.48	0.94	3.87	0.92	1.7	2.0	8.6	5.7	4.6	0	+390
3.	C	No	1978	7.5	1.24	5.72	6.61	2.66	8.9	0.4	7.4	3.9	7.7	0	-168
4.	D	Yes	1977	7.9	0.32	0.56	2.74	2.70	0.4	0.2	7.7	5.2	5.6	2.14	+657
	RIVERS														
5.	Colorado	No	1943	*	1.06	6.90	4.06	2.64	2.1	6.4	7.3	2.2	4.6	0	-702
6.	Pecos	*	1946	*	3.21	26.48	11.52	3.18	12.0	23.1	6.7	3.2	8.5	0	-4445
	SEWAGE WATER														
7.	Morro Bay effluent	No	1976	7.6	2.0	6.79	11.69	8.28	9.0	1.7	6.9	6.4	15.9	1.49	+1015
	WASHINGTON WELL														
8.	North central area	*	1944	7.8	0.64	5.32	1.31	5.03	0.1	1.8	7.1	0.8	1.8	0	-220

* information not available
** lbs/ac ft of water. negative values indicate gypsum deposited
*** Source of data for the 8 waters is given below

1-4 Personal data from files

5 USDA Handbook No 60. **Diagnosis and Improvement of Saline and Alkaki Soils (1954)**

6 FAO Irrigation and Drainage Paper No 29. **Water Quality for Agriculture.** R S Ayers and D W Westcot (1976)

7 Wildman, W E., R L Branson, J M. Rible and W E Cawelti. Irrigation **trial with Morro Bay wastewater,** Calif. Agric., May 1977, pp 36-37

8 Harley, C P and R C Lindner. **Observed responses of apple and pear trees to some irrigation waters of north central Washington.** Proc. Amer Soc. Hort. Sci. 46 35-44. (1945)

Permeability problems on Nos. 1, 2 and 4 are due to low salt content as well as to gypsum requirement.

The adj. SAR value of 8.5 for No. 6 (Pecos River) indicates a potential permeability problem due to sodium, however with the water supplying over 2 tons of gypsum per acre foot, one should be safe in predicting that permeability problems will not occur. The sodium chloride content of this water will present problems unless careful management is used.

Eaton's Gyp. Req. shows that the Colorado River is an excellent source of gypsum. This river has received a bad reputation in the past because of it's relatively high total salt

content, but well over half of the salt content is gypsum a benign salt for agriculture.

Morro Bay Effluent (No. 7)

From looking at the Permeability Evaluation of the Morro Bay effluent (No. 7), one would predict permeability problems from sodium buildup. Extensive tests with this water, however, showed that soil SAR values leveled off at 4.5 to 5.5 after 5 feet of water had been applied and did not increase when up to 17 ft of water had been applied. What happened?

The logical explanation is that the soil was kept wet enough so that calcium carbonate did not have a chance to precipitate. The entire 17 feet of water was applied within a year this in a cool climate. The permeability evaluations by adj. SAR and Eaton's Gyp. Req. are based on lime (calcium carbonate) precipitating out as the soil dries. With the large amounts of water applied, much of the bicarbonate would be leached below the root zone and thus not have a chance to react with calcium to precipitate lime. Supporting this explanation is the fact that the soil SAR actually decreased after the water application rate was doubled during the course of the experiment.

The preceding explanation is in agreement with a study that measured lime precipitated from irrigation water applied to a California citrus grove over a 38 year period. The amount of lime precipitated was less than expected in 2 of the treatments and the authors concluded that "The most logical explanation for the low amounts of $CaCO_3$ precipitated is that the soil was well leached."

Both the Morro Bay effluent data and the 38 year citrus grove experiment indicate that with a well drained soil and high water application rates, the harmful permeability effects of $CO_3 + HCO_3$ are greatly reduced. The same would be expected to hold true for drip irrigation, where soils are kept on the wet side. Under such conditions, the SAR values (which consider only Ca+Mg and Na) would better predict permeability effects; this was indeed the case with the Morro Bay effluent.

The Morro Bay effluent data show that rigid interpretation of water analysis data should be avoided, particularly when $CO_3 + HCO_3$ are involved. Eaton recognized this fact when introducing his Gypsum Requirement formula: "The factor here suggested for bicarbonate precipitation ($HCO_3 X 0.7$) may fit some situations well enough, but frequent and possibly wide departures will inevitably occur."

Washington State Well (No. 8)

If you took the water analysis data for sample No. 8 to 10 different water quality experts, at least 9 would say that the water quality was excellent for agriculture and that no problems should be anticipated other than possible scale buildup on pump bowls. The study from which this water data was taken states, however, that apple and pear trees irrigated with such waters over a period of years show "definite manifestations of vigor decline accompanied by varying degrees of chlorosis". Examination of tree roots showed lime incrustations around many of the roots and the decline and chlorosis was attributed to these incrustations.

The pH_c value and the Ca + Mg and $CO_3 + HCO_3$ content would predict lime deposition, but would not predict any problems from such deposition. Perhaps roots of some plant species encourage lime precipitation around the root itself.

The Washington State study also warns against rigid interpretation of water analysis data. Available criteria are guidelines only.

Increased Hazards from Sprinkler Irrigation

Leaves absorb both sodium and chloride, therefore sprinkler irrigation can present a hazard to sensitive crops. For sprinkler irrigation, both sodium and chloride should be less than 3 meq/l; when sprinklers are used for crop cooling (frequent on-off cycles), sodium and chloride should be less than 2 meq/l.

If leaf burn does occur when using sprinklers, irrigate at night; avoid irrigating during the hottest part of the day or during windy periods as conditions conducive to high evaporation will increase leaf burn. Increasing the speed of rotation of sprinkler heads will reduce leaf burn hazard by not allowing salts to concentrate (through evaporation) in water that has been applied.

Bicarbonate contents in excess of 1.5 meq/l can give white deposits (mainly lime) on leaves and fruit. Again, night sprinkling will minimize this problem (if it is a problem). Neutralizing the bicarbonate by the addition of acid to the water is a satisfactory alternative.

Water Amendments

As indicated previously, nothing can be done to change the quality of a water that has an excess of the 3 main toxic constituents, however when water quality is impaired because it has a potential permeability hazard from sodium buildup, the quality of the water can be improved by the addition of amendments.

A look at the formula used to calculate permeability hazards shows that a reduction in permeability hazard will occur by increasing the Ca content or by reducing the HCO_3 content. Addition of gypsum (calcium sulfate) is a common method of improving the Ca content of waters. Addition of sulfuric acid or SO_2 will reduce theHCO_3 content. Amendments do not have to be added directly to the water, but can be applied to the soil on which the water is to be used.

Chapter 4 discusses amendments in more detail.

Long Term Effects of Water on Soils

It is written (or some day will be): "as the water is, so then shall be the soil." If a given soil is irrigated with a given water over a long period of time, the soil will assume the characteristics of the water. In such cases, a look at water analysis data can provide an insight into the soil, even if no soil analysis data are available. Conversely, soil analysis data can indicate the chemical composition of the irrigation water used.

An interesting corollary to the above is water's effect on soil pH. The acid soils of the world invariably occur in high rainfall areas. Rain water, which has a high pH_c has acidified the soil.

Much of the irrigation water used on the east side of the San Joaquín Valley in California is runoff from the Sierras. This water, not having traveled far, is relatively pure and has a high pH_c. In effect, by using transported rainwater from the Sierras, some land on the eastern side of the San Joaquín Valley has been turned into the equivalent

of a high rainfall area.

How long does it take for a high pH_c water to acidify a soil? A rough approximation can be made by using the calculations used to derive pH_c. Assuming the following water content:

Ca+Mg = 0 62 meq/l; Na = 0.20 meq/l; CO_3+ HCO_3 = 0.52 meq/l, then

pH_c = 8.92 where a = 2.12, b = 3.50 and c = 3.29 (see table for calculating pH_c)

then,

1. Determine what value factor "c" should have in order to make the water a neutral water (pH_c of 8.4); "c" should be 2.77 in order to give a pH_c of 8.4 (a + b + 2.77 = 8.4).

2. From the pH_c table, determine the CO_3+ HCO_3 content needed to give a "c" value of 2.77. The answer is 1.69 meq/l.

3. Determine the difference between the CO_3+ HCO_3 content needed to give a neutral water and the actual content:

　　　1.69-0.52 = 1.17 meq/l of HCO_3 difference

This is the bicarbonate deficit of the water (compared to a neutral water having a pH_c of 8.4).

It takes roughly 135 lbs of 98% sulfuric acid per acre foot of water to neutralize the bicarbonate represented by 1 meq/l. Therefore, an acre foot of water that has a bicarbonate deficit of 1.17 meq/l has the acidifying potential of 158 lbs of sulfuric acid (135 X 1.17). Using 3 acre feet of this water each year can be the same as adding 474 lbs of sulfuric acid per acre each year and can cause significant soil acidification over a period of years if the soil does not contain lime*.

* if the soil has a high lime content, the amount of acid will have no effect on soil pH until the lime is neutralized (soil pH stays in the 7.2 to 7.7 range as long as there is significant lime in the soil). The soil series (from a soil map) will tell whether a given top soil contains lime in it's virgin state (use of low pHc water over a period of years can add lime to a lime free soil). A lab test can also be used.

Over a 10 to 20 year period, the water with a pH_c of 8.92 can have a significant effect on the pH of coarse textured soils that do not contain lime. Under a drip irrigation system that wets ¼ of the total soil, the acidifying effects will take place 4 times as fast.

In the case of a water that deposits lime (pH_c less than 8.4) it can similarly be determined how much lime the water will deposit per acre foot used by calculating the bicarbonate excess (rather than deficit) of the water (i.e., the amount of bicarbonate in excess of that needed to give a pH_c of 8.4). For each meq/l of HCO_3 excess, the water will deposit 135 lbs. of lime per acre foot of water used. A lime depositing water will tend to stabilize soil pH in the 7.2 to 7.7 range (and will gradually raise the pH of an acid soil to this range).

Some fieldmen are rightfully concerned about the acidifying effect of nitrogen fertilizers on soils. On non-calcareous soils, continued application of acidifying N fertilzers will

lower soil pH possibly enough to be detrimental to crop growth.

On a soil that contains 40,000 lbs of lime per acre foot (as some soils do) the acidifying effects of N fertilizers are of no immediate concern. On soils that do not contain lime, the acidifying effects of most N fertilizers can be easily offset if the irrigation water has a low pH_c. (see chapter on nitrogen for a further discussion of acidifying effects of N fertilizers).

Acidifying N fertilizers in combination with high pH_c irrigation water will eventually cause excessive soil acidity on soils that do not contain lime in the top soil. This combination has caused excessively acid soils on the east side of California's San Joaquín Valley. Use of elemental sulfur in pest and disease control programs will compound such acidity problems.

It should be remembered that pH_c values indicate a *tendency* to dissolve or precipitate lime. Calculations meant to predict a water's long term effect on soil pH are rough estimates only and are not meant to be precise.

Water as a Source of Nutrients

House plants irrigated with tap water thrive the same plants irrigated with distilled water can do poorly. Why?

Obviously there are nutrients in tap water that plants can use. All water sources pass through mineral strata prior to being tapped for irrigation. Mineral content of water varies, depending on where the water comes from and where it's been.

The amount of nutrients supplied by an acre foot of a given water source can easily be calculated from water analysis data. First determine the amount of the nutrient in ppm, then multiply by 2.7 (an acre foot of water weighs 2.7 million lbs.) to get lbs per acre foot.

Most water sources in the western U.S. contain sufficient magnesium and sulfur to supply a crop's needs. Crop response to sulfur in the western U.S. virtually always occurs when the crop is dependent solely on rainfall for it's water or when irrigation is from a water source with a very low sulfate content. As little as 5 lbs of S per acre foot of water will supply the sulfur needs of most crops. This is equivalent to a SO_4 content of 5.5 ppm or 0.12 meq/l.

Of the 3 major nutrients, water is rarely a significant source of potassium or phosphorus but some waters have a high enough nitrate content to supply a good portion of a crop's N needs. Needless to say, this can be a drawback for crops that are sensitive to excess N.

Comparing Amounts of Sodium and Chloride Added   by Water to Amounts

Added by Fertilizers

Table 1 shows that a good water (containing 6.5 meq/l Na and 4.2 meq/l Cl) can supply 400 lbs. of sodium and 400 lbs. of chloride per acre foot of water used. Assuming 3.5 acre feet of water are used during the growing season, over 1400 lbs each of sodium and chloride would be added to the soil by such a water. Table 1 says that most crops can take the addition of 1400 lbs of sodium or chloride during a growing season with no

undue concern about adverse effects.

There are 2 fertilizer materials that contain significant amounts of sodium and chloride: sodium nitrate (or nitrate of soda), a nitrogen fertilizer, and potassium chloride (or muriate of potash), a potassium fertilizer. Many fieldmen are leery of recommending these materials because of their sodium or chloride content, although muriate of potash is much more economical than other potash sources and there are instances (on acid soils, or where a quick N boost is desired) where sodium nitrate might be practical.

To determine if such materials are safe, determine the amount of sodium or chloride supplied by the material and add to this figure the amount supplied by the irrigation water during the growing season. If the total is less than 1400 lbs, the material can be safely broadcast (for very sensitive crops a 700 lb limit should be used; for crops such as avocados and strawberries, that are extremely sensitive to chloride, no chloride should be applied).

Examples:

1. Is it safe to broadcast 100 units of N as sodium nitrate to a crop of corn if the water supply contains 2 meq/l Na? (assume 3.5 acre feet of water used during the growing season).

a)   Na supplied by water during season = 435 lbs (2 X 23 X 2.7 X 3.5)

b)   Na supplied by sodium nitrate = 168 lbs (sodium nitrate is 16% N, 27% Na; 625 lbs. of material supply 100 lbs of N and 168 lbs of Na)

c)   total sodium added = 603 lbs.

Answer: Why not?

Question: How would the sodium content from the above material effect water penetration?

Answer: Not much. If you spread the 168 lbs of sodium over 3.5 acre feet of water you increase the effective sodium content by 17.7 ppm or 0.77 meq/l. This amount of sodium increases Eaton's Gyp. Req. by +77 lbs/acre foot of water (0.43 X 0.77 X 234). If water penetration was a concern, gypsum could be added. Water penetration for the initial irrigation might be poorer, but should improve during subsequent irrigations.

2. Is it safe to broadcast 200 lbs of K2Ü as muriate of potash to a crop of tomatoes if the irrigation water contains 1.5 meq/l Cl? (assume 3.5 acre feet of water will be applied during the growing season).

a)   Cl supplied by water during season = 503 lbs

b)   Cl supplied by muriate of potash   =   170 lbs (muriate of potash is 61% K_2O; 328 lbs supplies 200 lbs K_2O and 1 70 lbs of Cl).

c)   total chloride added = 673 lbs

Answer: Yes

It should be noted that the above examples specify broadcast application. Band application of the same materials would be too hazardous for many crops, especially in the seedling stage.

General References

1. 1 Ayers, R.S. and D.W. Westcot, **Water Quality for Agriculture,** Irrigation and Drainage Paper No. 29, Food and Agriculture Organization of the United Nations (FAO), Rome 1976.
2. Eaton, Frank M., **Significance of carbonates in irrigation water.** Soil Sei. 69:123-134 (1950).
3. Eaton, Frank M., **Total salt and water quality appraisal,** pp. 501-509, in Diagnostic Criteria for Plants & Soils, Homer Chapman Ed., University of California Div. of Agric. Sciences, (1966).
4. Stromberg, L.K., **Water Quality for Irrigation,** Fresno County Ag Extension Service, 1720 S. Maple Ave., Fresno, Ca. 93702. (1975).